INTRODUCTION AND KEY MESSAGES

Floods are the most destructive, most frequent and most costly natural disasters on earth. While harmful floods have happened throughout human history, flood damages have soared in recent decades, despite the expenditure of hundreds of billions of dollars on flood control structures. This is partly because global warming is causing more severe storms, and partly because of growing populations and economic activity on floodplains. It is also because flood control technologies and approaches often prove counterproductive. Improving our ability to cope with floods under the current, and future, climates requires adopting a more sophisticated set of techniques – the "soft path" of flood risk management, which aims to understand, adapt to and work with the forces of nature.

There are three main reasons why conventional "hard path" flood-control – based on dams and levees (embankments) – is not working. First, no complex engineering system can be totally fail-proof. Second, they have too often been based on an incomplete understanding of the workings of rivers and coasts. Third, they encourage the intensive development of flood-prone areas while discouraging investments in other flood-proofing measures and in preparations for flood evacuations. While hard flood control can prevent most "normal" floods, in the long run it tends to increase damage from severe floods. It also causes major harm to riverine ecosystems.

Dams and levees set off profound changes in the ways in which water and sediment flow through watersheds. This can increase flood damage for reasons such as:

- reduced channel capacities, because of sediment deposition on river beds;
- faster-flowing floodwaters due to straightening (and thus shortening) and narrowing of rivers;
- loss of sediment flows, leading to subsidence of deltas and coastal erosion.

The breaching of levees and dams (and the careless manage-ment of dam releases) cause extremely destructive floods because they tend to happen without warning and create fast-moving flood waves.

Climate change is expected to dramatically increase the size and frequency of floods. Structural flood control is based on the assumption of a static climate. In this fictitious world, engineers can calculate the probability of a flood of any given size occurring in any year. Dams and levees are designed to withstand a particular "return flood." But in the real, warming world, it is impossible to calculate meaningfully the size of any given return flood. The inflexibility of hard flood control is a major weakness not only because climate is changing, but also because the timing and size of floods change over time due to urbanization and other land-use alterations as well as natural geomorphological processes.

Flood risk management is flexible, in that it seeks to reduce damage from any size of flood, and adaptive in that it seeks to respond to the hydrological changes caused by changing land use and river morphology. Flood risk management assumes that floods will happen and that we need to learn to live with them as best we can, reducing their speed, size and duration where possible; getting out of their destructive path, and doing our best to protect our most valuable assets. It assumes that all flood protection infrastructure can fail and that this failure must be planned for. It is also based on an understanding that floods are not inherently bad – and indeed that floods are essential for the health of riverine ecosystems.

Key elements of flood management in a changing climate include:

1. Slow the flood: Strategies to reduce the speed and size of floods include moving embankments back from rivers and restoring wetlands, floodplains and meanders, and slowing down urban run-off. These measures also have major ecological, aesthetic and recreational benefits.

2. Improve emergency procedures: Possibly the most important measures in terms of saving lives are to improve flood forecasting, warning and evacuation procedures. It is also vital to prepare strategies in advance to help households and communities recover from the impacts of floods.

3. Move out of harm's way: A vital part of reducing damage, especially in less densely populated areas such as the US, is to discourage people from living in the areas most vulnerable to floods. Floodplain management includes planning regulations to discourage new floodplain development, and financial incentives for people living in the riskiest areas to move to higher ground.

4. Protect the most vulnerable buildings and areas: Flood risk management includes structural measures such as flood-proofing of individual buildings (for example, by raising them on stilts or mounds) and communities (e.g., building flood shelters and flood-protected water sources), the building of floodplain storage and bypass systems (areas of sparsely or undeveloped land which can be used to divert or store high floods), and the judicious use of well-maintained embankments for vulnerable urban areas.

5. Improve dam management: In many countries, dams worsen flood damages when they overtop, collapse or are poorly operated (as when reservoirs are kept full in order to maximize power generation, leaving little room for flood storage). Operating rules for dams should be developed with opportunity for public input, published, and stringently enforced. A safety assessment of existing dams is another critical issue; plans for removing unsafe dams should be prioritized. ■